ISSN 0543-5846
METABK 54(2) 395-398 (2015)
UDC – UDK 620.193:621.791.052:620.18:621.794=111

RESEARCHES ON CORROSION CRACKING PHENOMENON THAT OCCURS ON WELDED OF AGRICULTURAL EQUIPMENT

Received – Prispjelo: 2014-05-18
Accepted – Prihvaćeno: 2014-10-20
Preliminary Note – Prethodno priopćenje

Welded construction equipments for agriculture are strongly stressed in terms of mechanics, but also in terms of environmental action and thus in many cases appears their wear by corrosion cracking phenomenon. After research it was noted that after a certain period of use of equipment, metallographic structure of welded steel structures has changed substantially and at the same time a change in the chemical composition of steel was also observed. In terms of chemical composition a reduction in carbon content was mainly observed, and an increase in sulfur content, determined mainly by the presence of large quantities of sulfur in the atmosphere. This sulfur in the atmosphere at the same time determines the acid action on metallic materials, by forming with water from precipitation of H_2S.

Key words: corrosion cracking, welded construction, metallographic structure, chemical composition

INTRODUCTION

Technological equipments used in agriculture are very strongly stressed from a mechanical point of view, yet they are subjected to the action of agents specific to work environment. A big problem of such equipment is the welded steel construction which over time has not been modernized but only suffered some repairs. The life span of these welded constructions is very much influenced by the evolution of the properties of the material in their structure [1, 2]. Thus following the research conducted it has been observed that materials in the welded structures underwent structural changes, but also changes in terms of chemical composition. Thus, a predominant phenomenon that has occurred refers to this in the welded constructions of the wear type corrosion cracking.

Wear of the type corrosion cracking is of great importance because its occurrence leads to the cracking of the parts and removing them from service before the scheduled date [3].

For a practitioner, knowledge of materials' susceptibility to corrosion cracking has special significance in terms of optimal design, meaning the ratio of mechanical application, material consumption, investment costs, operation and maintenance, other influences (environment, human factor, etc.).

Traditionally in most cases, as a parameter on the susceptibility to corrosion cracking still serves, the so-called durability of the nominated material, in an aggressive environment, in the circumstances of a concomitant mechanical stress [4, 5] In terms of technological exploitation, tears or disposal by ruptures are due, in their vast majority, to the extension of the size of a crack-type defect as a result of corrosion, respectively of the action of an aggressive environment, as the effect of cyclical variability in the intensity of mechanical stress (exhaustion, etc.). The phenomenon is specific especially for breaks occurring for moderate intensities of the mechanical stresses, without a prior global plastic deformation of the affected element (cracked element), [6, 7].

The disposal by corrosion cracking goes through three stages:

- stage 1 – formation of primers (of the type of light tracing by scoring, Figure 1 a) on the metal surface;
- stage 2 – the primer becomes a crack (Figure 1 b) whose size continues to grow slowly froma macroscopic point of view;
- stage 3 – tearing (Figure 1 c) when the crack – expanding – reaches a certain size (lenght), big enough, called critical.

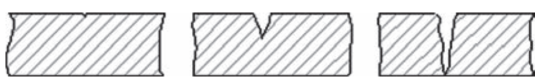

a) b) c)

Figure 1 Stages of corrosion cracking

From the information presented above we note that the evolution of a crack and the way in which it spreads, i.e. propagates, depends on the status of existing unitary stresses in the area where it is placed. Corrosion cracking also depends to a very large extent on external

I. Sărăcin University of Craiova, Faculty of Agriculture, Romania.
G. Paraschiv, Polytechnic University of Bucharest, Romania.
O. Pandia, I Bozgă, D. Toma University of Agricultural Sciences and Veterinary Medicine Bucharest, Romania

chemical agents that act on the part or equipment subject to research.

MATERIALS AND METHODS

Welded constructions used in agriculture are subjected to cyclic fatigue, but they also work in a chemically aggressive environment. The aggressiveness of the environment in which these constructions work can be explained by the presence in the atmosphere of large quantities of chemicals that can act as an aggressive environment. The aggressive work environment is characterized especially by the presence in the atmosphere of large amounts of sulfur resulting from the contact with the soil of the agricultural equipments.

These chemical elements, under certain conditions of pressure and temperature can form certain compounds that may have corrosive action on metallic materials. Thus, sulfur in contact with moisture in the atmosphere can cause the production of sulfuric acid (H_2SO_4) respectively of hydrogen sulfide (H_2S) which is are very corrosive substances for metallic materials.

If we take into account the fact that in agriculture in the welded constructions there is a random distribution of efforts, all possibilities of application should be taken into consideration. Thus, according to the relative movement of rupture surfaces, on either side of the plane where the crack extends, its evolution, and therefore its propagation can be achieved in accordance with the following basic modes of travel (Figure 2).

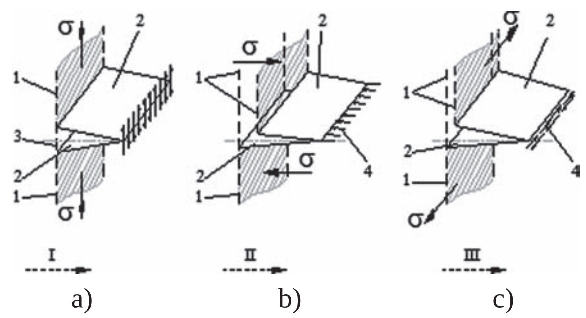


Figure 2 Travel of the rupture surfaces

- mode I – the crack extends through the opening, the points belonging to the crack surface shifting normally in the crack plane (Figure 2 a);
- mode II – the crack extends by straight, frontal sliding, the shifting of the points belonging to the crack surface being done in the crack plane, perpendicular to its edge and in the direction of its advancement (Figure 2 b);
- mode III – the crack extends by curve, lateral or spiral sliding, the shifting of the points belonging to the crack surface being also done in the crack plane, but parallel to its front (Figure 2 c).

Obviously, all other possible cracking modes can be described by the superposition, respectively by the appropriate combination of the three fundamental modes indicated.

With the appearance of the cracks, the unitary stresses σ change in value. The intensity factor of the mechanical stress, denoted by K, represents the measure of the amplification of unitary stresses respectively σ, generated by the presence of a crack, compared to the same nominal unitary stresses, which exist in an element in the absence of the crack. The values of K are always higher than one depending on the geometry of the structure or system element studied and the length of crack at a given point in time.

Slow cracking in a corrosive environment can be fully described only by means of the intensity factor of the voltage, thus the method is based on the factor K.

For high levels of mechanical stress intensity, there isn't a unequivocal correlation between the K factor and the speed of evolution of corrosion cracking. This correlation does not allow forecasting future expansion of the cracks detected at one time. This time, the maximum utility only shows the results of the measurement under constant load of the rate of crack extension.

It has been demonstrated that the cracks that occur on the surfaces of parts could be the main cause of shortening the operational reliability and safety for both metal constructions for agriculture and the equipment to which they belong.

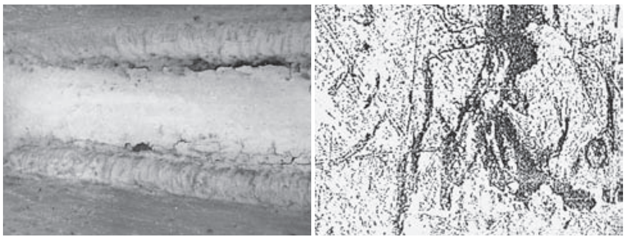
Working in harsh environments, even in the case of stainless steel, can cause catastrophic wear or premature refurbishment or replacement of parts. Due to aggressive environments and mechanical stress in the structure of materials, several structural changes may appear, which constitute the causes of the phenomenon of corrosion cracking, but also of the distortions. Also, the occurrence of material fatigue determines the localization of geometric structural discontinuities, secondary phases, goals, defects. These areas can act as stress concentrators that may lead to local plastic deformation of the material. Under aggressive environmental conditions, this kind of non-homogeneities and discontinuities may appear on the material's surface and due to corrosion, amplified mechanical process of variable requests.

Construction steels for general use, compared with carbon steels, have become widely used in the construction of machinery for agriculture, due to their characteristics that allow the appropriate behavior to combined, respectively mechanical stresses in a corrosive environment. This study focused on the characterization of the behavior in terms of variables applications in corrosive environment of OL52.4K steel, which is used in the production of resistance elements (beams, columns, sections, rails, brackets, etc.).

In the experimental research, initially an identification was performed of the areas in the welded construction where corrosion was most pronounced, and to achieve this, an equipment type Laptoscop was used, which allowed the measurement of the oxide layer thickness. Also, after identifying the areas with the highest corrosion level, the areas where the phenomena of corrosion cracking occurred have also been determined, and the material in these areas underwent structural analysis, of the chemical composition and of the mechanical characteristics.

RESULTS AND DISCUSIONS

Welded constructions that are part of the structure of the technological equipment used in agriculture are very complex structures. Thus, the experimental research was focused on those areas where by a visual analysis we could observe the presence of corrosion of the materials, Figure 3.

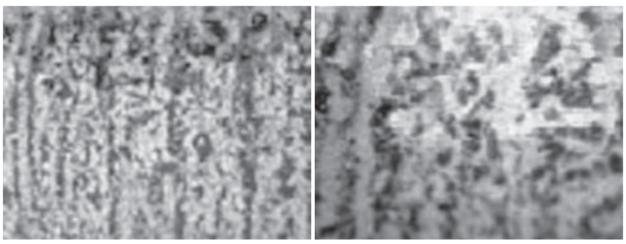


a) b)

Figure 3 Presentation of the corrosion phenomenon of the material in the welded constructions a - general view of the areas subjected to corrosion, b- corrosion cracking in the structure of the material

From the early research conducted we have noted that the areas most affected by the phenomenon of corrosion are welded horizontal surfaces and their surrounding areas. This demonstrates once again that the materials in welded constructions are strongly affected by the presence of a corrosive environment. The areas where corrosion was observed have initially undergone the process of oxide layer thickness identification. Thus, many areas have been identified where the oxide thickness exceeds 100 / mm, and then material was collected from these areas, and its characteristics were compared with those of new material. For the identification of all areas where the occurrence of corrosion cracking was possibile, it was necessary to perform a large number of measurements determined by the complexity of the welded construction and the large number of areas where corrosion was present.

The new (unused) material, as well as the used one (taken from the used construction) were subjected to a microscopical analysis, Figure 4, from which we can note that the most affected, from a structural point of view, as well as with respect to corrosion, was the superficial layer of the used material which comes into direct contact with the aggressive environment in which the welded construction operates.



a) x100 b) x100

Figure 4 Microscopical analysis of the samples from OL52.4K a) state of new material; b) state of used material

Following the microscopic analysis of the new material, as well as of the used one, an analysis of their chemical composition was also performed and the results are presented in Tables 1 and 2.

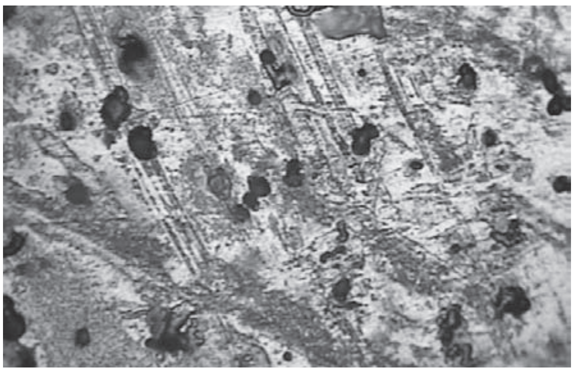
Table 1 **Chemical composition of new material / wt. %**

C	Mn	Si	S	P	Al	Ti	V
0,217	1,6583	0,053	0,025	0,021	0,011	-	-

Table 2 **Chemical composition of used material / wt. %**

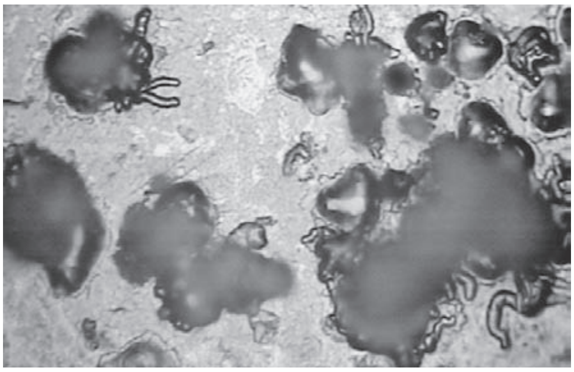
C	Mn	Si	S	P	Al	Ti	V
0,183	1,260	0,049	0,057	0,0118	0,01	-	-

From the analysis of the data presented in Table 1 and 2 we observe mainly a reduced concentration of carbon in the used material, but a substantial increase in the concentration of sulphur. This is explained by the fact that some of the carbon is separated in time and diffuses outward or forms new structural constituents and the increase of the sulphur concentration is explained by its diffusion from the aggressive environment where these devices are used. Thus, a reduction in the carbon content causes a decrease of the tensile strength and hardness of the material which reduces the capacity of the welded construction to take different loads. Increased sulphur content causes the occurrence of strong segregationsm making the materials brittle. Also, the presence of sulphur in large quantities can cause segregation of the carbon, forming nests graphite, and this is explained by the fact that sulphur is a graphitising element. From the analysis of the results on the chemical composition we also observe that in the used material there are decreases in concentration for most alloying elements, and this may cause a reduction in mechanical and operational characteristics of the used material. All these changes observed in the chemical composition of the used material require the implementation of a struc-



x 500

Figure 5 Metallographic structure of the new material



x 500

Figure 6 Metallographic structure of the used material

tural analysis of the two materials, namely the new material, Figure 5 and the used material, Figure 6.

The metallographic structure of the new material is characterized by small clusters of carbon in isolated nests with primary cementite with needle aspect, in substance perlite, and in the case of the metallographic structure of the used material there was an increase in the volume of carbon nests at the expense of the cementite which is almost nonexistent in the same fund as perlite.

These structural changes again demonstrate that the phenomenon of corrosion cracking can occur very easily in the welded construction material and at the same time a reduction of the mechanical characteristics of the used material occurs.

The reduction of the mechanical characteristics, but also the presence of corrosion cracking determine the decommissioning of this technological equipment, and a decrease of their operational safety.

In this respect different mechanical characteristics have been established for the two materials analyzed and the results are presented in Tables 3, Table 4 and Table 5.

Table 3 **Tensile strenght, *R*m of OL 52.4K / MPa**

New material	529
Used material	421

Table 4 **Toughness, KCU of OL 52.4K / J/cm²**

New material	63
Used material	51

Table 5 **Yield strength and elongation**

OL 52.4K	Minimum *R*e / MPa	*A* / %
New material	351	21
Used material	327	15

CONCLUSIONS

Following experimental research and the experimental results obtained the following conclusions can be drawn:

- welded constructions of the technological equipment in agriculture facilities are strongly subjected to corrosion cracking;
- welded construction material suffers structural changes in chemical composition, but a reduction in its mechanical characteristics was also found;
- corrosion cracking that occurs is mainly due to aggressive working environment in which this equipment is operated (the presence of sulphur in the atmosphere and the formation of H_2S-hidrogen sulfide respectively H_2SO_4- sulphuric acid);
- corrosion cracks appear especially on the horizontal surfaces of welded constructions and in this respect we recommend the adoption of changes in the construction, but also the adoption of thermal and thermochemical treatments to increase corrosion resistance of the materials;
- results can be used to analyze other welded constructions working in corrosive environment.

REFERENCES

[1] D. Dobrotă, Metalurgija, 53 (2014) 2, 179-182;

[2] A. King, G. Johnson, D. Engelberg, W. Ludwig, J. Marrow, Materials Science, 321 (2008) 5887, 382-385;

[3] M.G. Petrescu, I. Nae, E.V. Laudacescu, R.M. Ellafi, R. M., Journal of Chemistry, 57 (2006) 8, 732-738.

[4] K. Sieradzki, R.C. Newman, Philosophical Magazine A, 51 (2006) 1, 95-132.

[5] O. Chivu, Metalurgija, 52 (2013) 4, 465-468.

[6] ANSI Z49.1, Section E5.4 pp. 12, American Welding Society, 550 NW LeJeune Road, Miami, FL, 2005,

[7] E. Bayraktar et al., Journal of Materials Processing Technology 145 (2004) 1, 27-39

Note: The responsible translator for English language is lecturer LUTA RODIAN, Craiova, Romania